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Utilization of Distillery Spentwash to Sustain Soil Health and Enhanced Yield of Maize in Entisol

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Field experiment was conducted during 2009 (August to December) in the Research and Development farm of M/s. Bannari Amman Sugars Distillery Division Ltd., Ealur, Erode to find out the optimum dosage of biomethanated distillery spentwash (BDS) and its effect on soil fertility and yield of maize. Different doses of BDS along with inorganic chemical fertilizers were assessed in maize (cultivar COH (M) 5). The soil nutrient parameters *viz*., pH, EC, organic carbon, exchangeable cations and macro nutrients were estimated at vegetative, flowering and post harvest stages along with and dry matter production, cob, grain and stover yields of maize. The results of the field experiment revealed that the application of BDS @ 100 kilo l per ha with recommended dose of NPK significantly increased the soil nutrient availability and yield parameters of the maize crop over recommended dose of fertilizer control.

Keywords: Distillery Spentwash, Entisol, Maize, Yield, Soil fertility.

The consumption of fertilizer has increased globally from 16 per cent to 56 per cent in developing countries. By 2025 AD, the annual nutrients requirement of our country would be around 45 million tonnes. The NPK fertilizer requirement of our country is 28 million tonnes but the quantity added through fertilizers is only 18 million tonnes with a gap of 10 million tonnes being mined from soil (FAO, 2010). But there is no scope for the increasing fertilizer production as there will be shortage of raw materials required for the manufacture of fertilizers. India currently generates over 1,10,000 million l of wastewater per day (Jadhav *et al.,* 2010). Water, a basis of life on this planet, is one of the natural resources that are indispensible for successful crop production. The availability of fresh water for irrigation is reducing day by day due to increasing demand for industry and domestic consumption. It is predicted that most of the Asain countries will face a severe problem related to water availability by 2025 (Singh, 1999).

Distilleries, one of the most important agro-based industries in India, produce alcohol from molasses. They generate large volume of foul-smelling coloured wastewater known as spentwash. For production of each litre of alcohol, 12-15 l of effluent is produced. Approximately 40 billion l of wastewater is generated per annum from 319 distilleries in the country (Kanimozhi and Vasudevan, 2010). The effluent causes concern of environmental pollution owing to its very high organic load, Biochemical oxygen demand (BOD) and Chemical oxygen demand (COD). After the recovery of the biogas, the distillery spentwash is referred as Biomethanated distillery spentwash (BDS). Being originated from a plant source, it contains large amounts of organic carbon, K, Ca, Mg and S and moderate levels of N and P and small quantities of micro nutrients and plant growth promoters viz., gibberellic acid and indole acetic acid (Murugaragavan, 2002). Spentwash, as substitute for market purchased inorganic fertilizer, has a great promise in future (Joshi and Singh, 2010). The present study was made to assess the optimum dosage of BDS and its effect on soil and yield parameters of maize in combination with inorganic fertilizers.

Materials and Methods

Field experiment was conducted during 2009 (August to December) at the Research and Development farm of M/s. Bannari Amman Sugars Distillery Division Ltd., Ealur, Erode where a distillery with spentwash generation capacity of 60 KL/day from molasses is operating since 1996. The study area covers a total area of 1360 sq km, located at 11°29' to 11°48'N latitude and 76° 50' to 77° 27' E longitude comes under western ecological zone at 600 m above mean sea level. The soil of the experimental area is Irugur series with the subgroup of *Typic Ustorthent* under the soil order Entisol. The annual precipitation is around 700 mm and minimum temperature ranged from 18 to 25°C and the maximum from 28 to 36°C. Different doses of BDS along with inorganic fertilizers using Maize hybrid COH (M) 5 as test crop were include in the treatments.The experiment was laid out in

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Randomized Block Design with three replications; seed rate adopted was 18 kg ha^{-1} with the spacing of 60 x 25 cm. The treatment consisted of T_1 - RD (Recommended Dose) NPK, T_2 - BDS @ 50 KL ha^{-1} + RD-NP, T_3 - BDS @ 50 KL ha^{-1} + RD-NPK, T_4 - BDS @ 100 KL ha^{-1} + RD-NP, T_5 - BDS @ 100 KL ha^{-1} + RD-NPK, T_6 - BDS @ 150 KL ha^{-1} + RD-NP, T_7 - BDS @ 150 KL ha^{-1} + RD-NPK. Spentwash was applied as per the treatment and incorporated into the soil at 30 days before sowing in order to reduce the BOD and COD load. The experimental plots were irrigated immediately after sowing. The recommended dose of fertilizers *viz.,* 75 Kg N, 75 Kg P_2O_5 and 75 Kg K_2O per hectare were applied as per the treatments at sowing and the remaining 75 Kg N was top-dressed at 30 days of sowing (DAS).

The soil samples were drawn at three stages *viz.,* vegetative (30 DAS), flowering (60 DAS) and post harvest (90 DAS). The collected soil samples were dried under shade, powdered with wooden mallet and sieved through 2 mm sieve and analyzed for various parameters. The organic matter content of the soil was determined by walkley and black method suggested by Nelson and Sommers (1982). Electrical conductivity (EC) and pH of the soil were estimated in 1:2.5 soil:water suspension by pH and EC meters. Available nitrogen was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956), available phosphorus by $NaHCO_3$ extract - colorimetric method (Olsen *et al.,* 1954) and available potassium and exchange cations *viz.,* Ca, Mg, Na and K were estimated by neutral normal ammonium acetate method (Jackson, 1973). The data were analyzed statistically and the treatment means were compared using LSD at 5 % probability (Panse and Sukhatme, 1985).

Results and Discussion

Soil pH and EC

Application of graded doses of BDS gradually increased the pH and EC of the soil (Fig. 1A). The highest increase in pH was recorded by BDS @ 100 KL ha^{-1} + RD of NPK (7.31, 7.28 and 7.22 at 30, 60 and 90 DAS respectively) which was on par with BDS @ 100 KL ha^{-1} + RD of NP (7.29, 7.25 and 7.17 at 30, 60 and 90 DAS respectively) and the lowest was recorded by RDF (6.78, 6.72 and 6.62 at 30, 60 and 90 DAS respectively). In general an increasing trend in soil pH was observed in BDS applied treatments compared to RDF. This increase in pH values of the effluent treated soil could be either due to alkaline reaction of the effluent or due to the increase in soil moisture with increasing C:N ratio of the waste water. This is in line with the findings of Magesan *et al.* (2000). The addition of distillery effluent regardless of rate raised the soil pH, owing to increase in soil K, Ca, Mg and Na levels and the organic matter oxidation brought out by microbial activity was responsible for increased pH of the soil treated with distillery effluent which is in accordance with the findings of Raverkar *et al.* (2000).

Table 1. Impact of BDS with inorganic chemical fertilizers on soil exchangeable cations at various stages of maize crop

Treatment	Exchangeable Ca(c.mol. (p^+) kg^{-1})			Exchangeable Mg(c.mol. (p^+) kg^{-1})			Exchangeable Na(c.mol. (p^+) kg^{-1})			Exchangeable K(c.mol. (p^+) kg^{-1})		
	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
T_1 - RDF	5.34	5.30	5.26	2.26	2.21	2.18	0.54	0.41	0.46	0.25	0.21	0.16
T_2 - BDS @ 50 KL ha^{-1} + NP	5.62	5.58	5.54	2.62	2.54	2.46	0.71	0.68	0.66	0.32	0.28	0.24
T_3 - BDS @ 50 KL ha^{-1} + NPK	5.71	5.64	5.52	2.68	2.62	2.60	0.75	0.71	0.66	0.40	0.32	0.26
T_4 - BDS @ 100 KL ha^{-1} + NP	6.07	6.01	5.98	2.90	2.88	2.83	0.92	0.88	0.82	0.56	0.45	0.48
T_5 - BDS @ 100 KL ha^{-1} + NPK	6.16	6.10	6.04	2.98	2.94	2.91	0.94	0.90	0.86	0.62	0.58	0.54
T_6 - BDS @ 150 KL ha^{-1} + NP	5.78	5.72	5.68	2.78	2.73	2.65	0.86	0.81	0.75	0.48	0.44	0.40
T_7 - BDS @ 150 KL ha^{-1} + NPK	5.88	5.84	5.81	2.85	2.81	2.74	0.88	0.82	0.79	0.52	0.48	0.42
		CD (0.05)			CD (0.05)			CD (0.05)			CD (0.05)	
T		0.11			0.08			0.03			0.02	
S		0.07			0.05			0.02			0.01	
T X S		NS			NS			NS			0.03	

RDF - Recommended Dose of NPK; BDS: Biomethanated Distillery Spentwash; DAP-Days After Planting

The EC of soil significantly changed between the treatments and stages due to BDS, application (Fig. 1B). In general, a decreasing trend was noticed with advancement of the stages which might probably be due to crop removal and/or due to the leaching of salts from surface to subsurface soil and the present results are in accordance with the findings of Hati *et al*. (2007). This increase was quite expected as the BDS had an EC of 35.23 dS m^{-1} due to heavy loads of salts. With respect to different treatments, BDS @ 100 KL ha^{-1} + RD of NPK showed the highest EC (0.55, 0.49 and 0.39 dS m^{-1} at 30, 60 and 90 DAS respectively) which was on par with BDS @ 100 KL ha^{-1} + RD of NP and the lowest was recorded by RDF (0.35, 0.29 and 0.26 at 30, 60 and 90 DAS respectively). The improvement of the soil physical structure is due to the application of BDS which would have facilitated the leaching of salts from soil (Seth *et al.*, 2005).

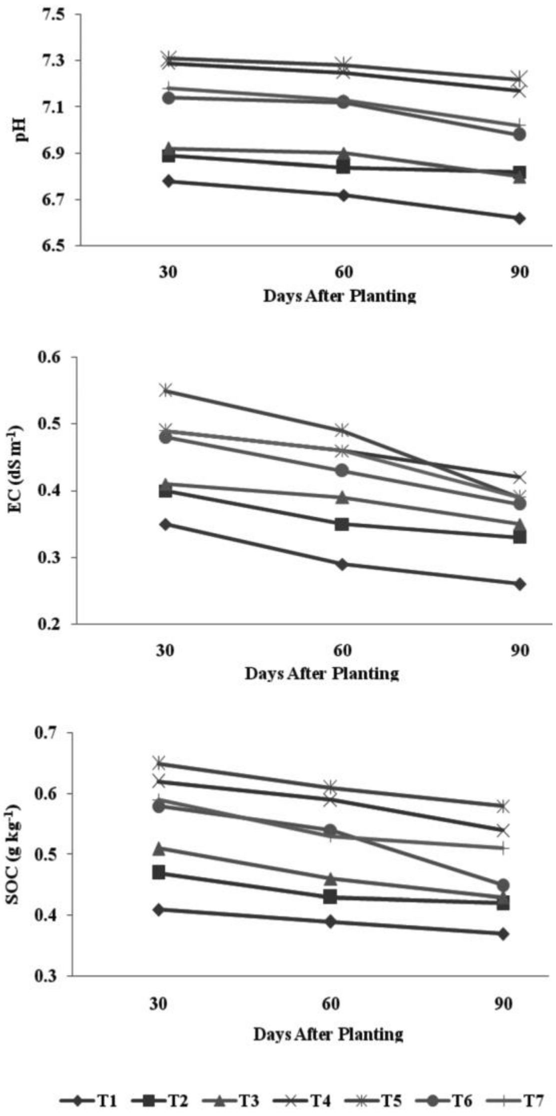

Fig. 1. Impact of BDS with inorganic chemical fertilizers on changes in pH (A), EC (B) and Soil Organic Carbon (SOC) (C) of soil grown with maize. T_1-T_7 treatments as detailed in materials and methods.

Soil organic carbon and exchangeable cations

The highest organic carbon content of 0.61 g kg$_{-1}$ was observed in the treatment which received the distillery effluent @ 100 KL ha$_{-1}$ + RD of NPK over RDF (0.39 g kg$_{-1}$) (Fig. 1C). The spentwash with high BOD and organic carbon content enriches the soil with organic matter. The decomposition and humification of the organic matter in soil supplied through distillery effluent, in turn increased the soil organic carbon. The high organic load of the distillery effluent might be the reason for increased organic carbon content of post harvest soil. The effectiveness of spentwash in increasing the organic carbon content was also reported by Selvakumar (2006) which was in close agreement with the present findings.

The exchangeable cations of soil were significantly increased due to application of different doses of distillery spentwash. The highest increase in exchangeable cations of 6.10, 2.94, 0.90 and 0.58 cmol (p$_{+}$) kg$_{-1}$ of Ca, Mg, Na and K respectively was recorded by BDS @ 100 KL ha$_{-1}$ + RD of NPK application which was on par with BDS @ 100 KL ha$_{-1}$ + RD of NP except exchangeable K and the lowest by RDF (5.30, 2.22, 0.47 and 0.21 cmol (p$_{+}$) kg$_{-1}$ of exchangeable Ca, Mg, Na and K respectively) (Table 1). The reason might be due to addition of K, Ca and Mg through the effluent addition (Kayalvizhi *et al.,* 2001) . High exchangeable sodium percentage, pH, presence of potentially determining ions such as CO_3^- and HCO_3^-, highly charged humus matter and highly increased specific surface of $CaCO_{3-}$ may also be supposed to be responsible for increased the exchangeable cations (Pushpavalli *et al*., 2002).

Soil Macronutrients

The available N, P and K contents of the soil significantly increased due to application of distillery effluent. Higher values were observed in the treatment which received BDS @ 100 KL ha$_{-1}$ + RD of NPK that recorded the highest available N content of 186 kg ha$_{-1}$ which was on par with BDS @ 100 KL ha$_{-1}$ + RD of NP (184 kg ha$_{-1}$) over RDF (104 kg ha$_{-1}$) (Table 2). The increased microbial activity on the added organic matter might have increased the available N level of the soil (Subash Chandra Bose *et al.,* 2002). The higher rate of mineralization and release of N from soil, addition of chemical fertilizers and effluent could have contributed for the increase in the available N content of the soil (Rakkiyappan *et al*., 2005).

Distillery effluent application remarkably increased the available P in the soil. The available P was significantly increased due to the application of graded dose of spentwash, the highest being for the application of BDS @ 100 KL ha$_{-1}$ + RD of NPK of 27.8 kg ha$_{-1}$ which was on par with BDS @ 100 KL ha$_{-1}$ + RD of NP (26.4 kg ha$_{-1}$) and the lowest was recorded by RDF (15.1 kg ha$_{-1}$) (Table 2). The significant increase in the available P in the soil due to the addition of P and HCO_3 through distillery effluent and production of organic acids would have helped in the solubility of the native soil P. Similar results were reported by Mahimairaja and Bolan (2004). Several fold increase in available P was observed due to different levels of spentwash application which may be possibly due to instantaneous addition of spentwash having considerable amount of P as well as the consequent dissolution of soil mineral P (apatite P). Though biomethanated spentwash was not acidic, its decomposition products release organic acids which might have solubilised the apatite P and thus increased the $NaHCO_3$ – P (Murugaraghavan, 2002).

Among the different treatments, basal

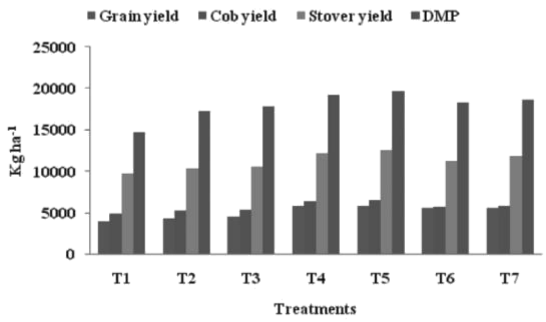

Fig. 2. Impact of BDS and inorganic fertilizers on grain, cob and stover yield and dry matter production of maize. T_1-T_7 refer the treatments as detailed in materials and methods.

application of 100 KL ha^{-1} + RD of NPK (472 kg ha^{-1}) recorded the highest K availability in the soil which might be due to the higher concentration of K in the spentwash (12,140 mg L^{-1}) (Table 2). The significant increased K due to the soil got increased 4 to 5 times due to the effluent irrigation which might be due to the fact that K was one of the components supplied in large quantities. The availability of K in the soil got decreased as the crop growth advanced which could be attributed to the uptake of K by the crop (Venkatakrishnan and Ravichandran, 2007).

Crop yield

The grain, cob and stover yields and dry matter production of maize were significantly increased in the distillery spentwash applied treatments compared to RDF (Fig. 2). Among the treatment BDS @ 100 KL ha^{-1} + RD of NPK recorded the higher grain, cob and stover yield and DMP of 5815, 6513, 12454 and 19687 kg ha^{-1}, respectively which was on par with BDS @ 100 KL ha^{-1} + RD of NP (5759, 6327, 12186 and 19176 kg ha^{-1}) and the lowest was registered in RDF (3917, 4864, 9765 and 14752 kg ha^{-1}). The distillery effluent is essentially a plant extract and contains high level of plant nutrients which were made available to the plant, thus resulting in better growth, development and yield of the crop. This is close agreement with the findings of Taradevibhukia *et al.* (2009). Addition of spentwash to supply nitrogen resulted in significantly higher growth parameters compared to chemical fertilization and this increase was significant throughout the phonological stages of crop growth. The reason was due to the increased nutrient supply and also their availability coupled with good physical properties exhibited by the application of spentwash (Madhumitadas *et al.,* 2010).

Table 2. Impact of BDS with inorganic chemical fertilizers on soil available nitrogen, phosphorus and potassium content at various stages of maize crop

Treatment	Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potassium (kg ha^{-1})		
	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
T_1 - RDF	112	103	99	15.8	15.3	14.2	178	126	104
T_2 - BDS @ 50 KL ha^{-1} + NP	146	140	131	19.4	18.9	18.1	248	199	172
T_3 - BDS @ 50 KL ha^{-1} + NPK	146	139	133	24.5	18.8	16.5	267	259	218
T_4 - BDS @ 100 KL ha^{-1} + NP	191	185	177	29.8	25.9	22.6	485	419	376
T_5 - BDS @ 100 KL ha^{-1} + NPK	193	187	179	30.9	27.8	25.3	491	476	446
T_6 - BDS @ 150 KL ha^{-1} + NP	166	162	148	22.8	22.5	21.8	384	304	272
T_7 - BDS @ 150 KL ha^{-1} + NPK	178	165	145	26.5	23.9	21.3	418	342	336
		CD (0.05)			CD (0.05)			CD (0.05)	
T		4.43			0.74			11.03	
S		2.90			0.49			7.22	
T X S		7.67			1.29			19.10	

RDF - Recommended Dose of NPK; BDS: Biomethanated Distillery Spentwash; DAP-Days After Planting

From the present investigation, it could be concluded that the application of BDS @ 100 KL ha^{-1} along with recommended dose of chemical fertilizers increased the soil pH, EC, organic carbon, exchange cations and macro nutrients status. These soil nutrient parameters are highly correlated with yield parameters of maize crop. Distillery spentwash from sugar mills hitherto considered as factory waste could be used as a source of nutrients to maize. Thus application of spentwash to the agricultural field, as an amendment, might be a viable option for the safe disposal of this industrial waste with concomitant enhancement in yield and soil nutrient properties of the maize crop. However, the level of application should be within the prescribed limit to avoid development of soil salinity in the long run and not to affect the ground water quality also.

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